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DESIGN AND IMPLEMENTATION OF MAXIMUM POWER POINT TRACKING USING WIND ENERGY SYSTEM

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Abstract- The project describes a maximum power point tracking (MPPT) scheme for a PMSG-based wind energy conversion system (WECS) in which a boost converter is used to handle a wide range of wind speeds. A closed-loop with an inverter forces the WECS to extract the maximum power available from the wind turbine by shifting the phase angle of output voltage at a given wind speed. The mathematical model of the wind power system is built and simulated by MATALB/SIMULINK software. Simulation results show that the proposed control scheme has a good dynamic performance and operates the wind generation system with the maximum efficiency. Functional approximation algorithm is being used for the wind system. The converter part is realized and MPPT is done for certain speed of wind.

Keywords- Maximum power point tracking, Permanent magnet synchronous generator, Wind energy, Inverter and Rectifier.

I. INTRODUCTION

With increasing concern of global warming and the depletion of fossil fuel reserves, many are looking at sustainable energy solutions to preserve the earth for the future generations. Wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another[1]. The common inherent drawback of wind is their intermittent natures that make them unreliable. In order for wind energy to be an attractive alternative, the wind turbines need to be very efficient in harvesting energy. The wind turbine can only provide a maximum power for a particular wind speed and an attempt to try and acquire more power by decreasing or increasing the load on the generator, will result in an inefficient transfer of power from the wind. In the large-sized wind power generation system whose output per generator like a wind farm is about 2000 kW, there are various problems - restrictions of an installation place, wind conditions, and introductory cost are high. In recent years, small wind power system having output about l00 kW is in practical use.

This project proposes MPPT scheme for a WECS with a PMSG. The major advantage of using a PMSG it is efficient, smaller in size, and easily-controllable as compared to direct current generator or induction generator and its ability to handle a wide range of rotor speeds which correspond to a large range of wind speeds[2]. In a PMSG, the frequency and amplitude of the output voltage vary with wind speed. In order to maintain a narrow range of dc link voltage, the proposed wind generation system uses a dc-dc converter with boost feature which can step up the rectified voltage by controlling its duty cycle. The blocks are implemented and simulated using MATLAB SIMULINK. Simulation results are provided to verify with the feasibility of the proposed system.

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II. WIND ENERGY CONVERSION SYSTEM

The typical wind energy conversion system is shown in Figure 1. The principle components of a modern wind turbine are the tower, yaw, rotor and the nacelle, which accommodates the gear box and generator.

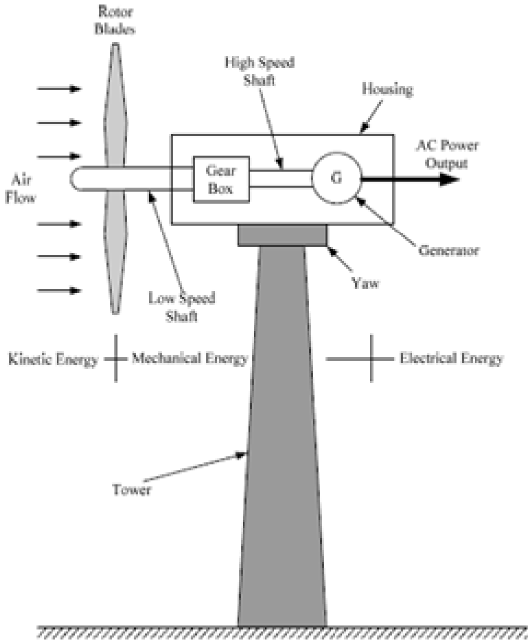

Figure 1. Typical wind energy conversion system

The tower holds the main part of the wind turbine and keeps the rotating blades at a height to capture sufficient wind power. The yaw mechanism is used to turn the wind turbine rotor blades against the wind. Wind turbine captures the wind's kinetic energy in the rotor consisting of two or more blades. The gearbox transforms the slower rotational speeds of the wind turbine to higher rotational speeds on the electrical generator side. Electrical generator will generate electricity when its shaft is driven by the wind turbine, whose output is maintained as per specifications, by employing suitable control and supervising techniques[3-5]. In addition to monitoring the output, these control systems also include protection equipment to protect the overall system. Two distinctly different design configurations are available for a wind turbine, the horizontal axis configuration and the vertical axis configuration. The vertical axis machine has the shape like an egg beater. However, most modern turbines use horizontal axis design.

A. Constant Speed and Variable Speed Wind Energy Conversion Systems (WECS)

Generally, there are two types of wind energy conversion systems: constant speed and variable speed systems, shown in Figure 2. The generator normally is a squirrel cage induction generator which is connected to a utility grid or load directly. Since the generator is directly coupled, the wind turbine rotates at a constant speed governed by the frequency of the utility grid (50 Hz) and the number of poles of the generator. The other two wind power generation systems, shown in Figures 2 are variable speed systems. In Figure 2(b) the generator is a doubly-fed induction generator (wound rotor) [21]. The rotor of the generator is fed by a back-to-back converter voltage source converter. The stator of the generator is directly connected to load or grid. Through proper control on the converter for the rotor, the mechanical speed of the rotor can be variable while the frequency of output AC from the stator can be kept constant. Figure 2(c) shows a variable speed system which is completely decoupled from load or grid through a power electronic interfacing circuit. The generator can either be a synchronous generator (with excitation winding or permanent magnet).

B. Wind Turbine Output Power Vs Wind Speed

A typical power Vs. wind speed curve is shown in Figure 3. When the wind speed is less than the cut-in speed (normally 3-5 m/s), there is no power output, between the cut-in speed and the rated or nominal wind speed (normally 11-16 m/s), the wind turbine output power is directly related to the cubic of wind speed[6]. When the wind speed is over the nominal value, the output power needs to be limited to a certain value so that the generator and the corresponding power electronic devices (if any) will not be damaged. In other words, when the wind speed is greater than the rated value, the power coefficient Cp needs to be reduced. When the wind speed is higher than the cut-out speed (normally 17-30 m/s), the system will be taken out of operation for protection of its components[7].

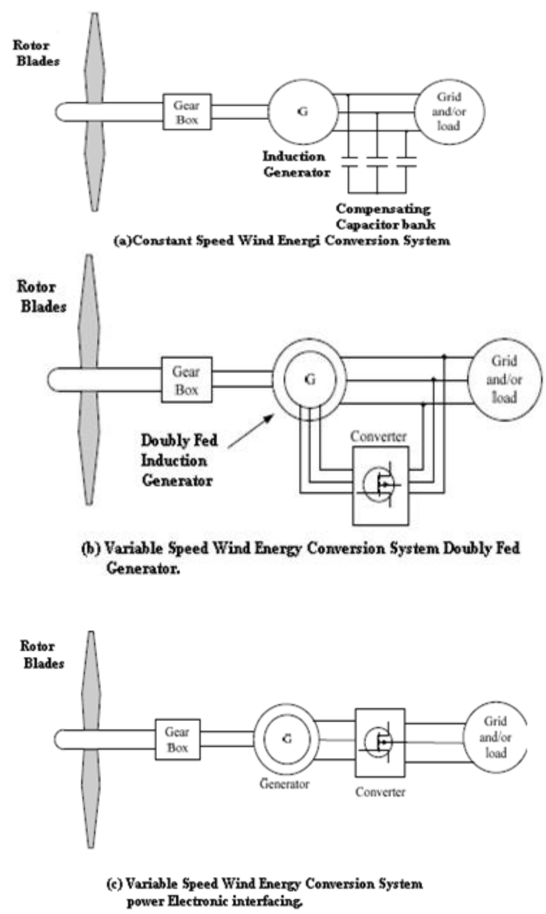

Figure 2. constant and variable speed wind energy conversion system

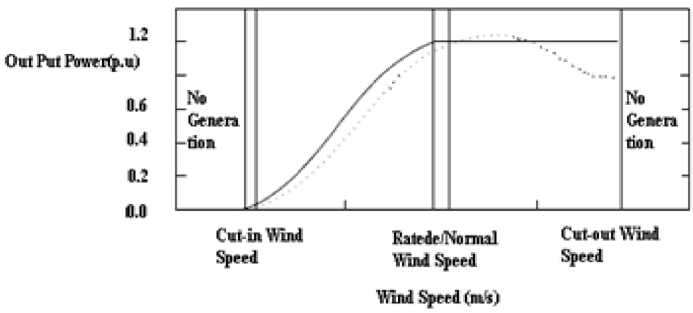

Figure 3. Typical curves for a constant speed stall controlled (dotted) and variable speed pitch controlled wind turbine

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There are several ways to control the wind turbine output power. The two common ways to achieve this goal are: stall control and pitch control. For a stall controlled wind turbine, there is no active control applied to it. The output power is regulated through a specifically designed rotor blades. The design ensures that when the wind speed is too high, it creates turbulences on the side of the rotor blades. The turbulences will decrease the aerodynamic efficiency of the wind turbine as a result. Pitch control is an active method which is used to reduce the aerodynamic efficiency by changing pitch angle of the rotor blades[8]. The maximum rate of change of the pitch angle is in the order of 3 to 10 degrees/second. It is noted from Figure 3 that a variable speed system normally has lower cut-in speed. The rated speed is also normally lower than a constant speed system. For wind speeds between the cut-in and the nominal speed, there will be 20-30% increase in the energy capture with variable speed compared to the fixed-speed operation shown in Figure 3. For a pitch controlled wind system, the power for wind speeds over the nominal value can be held constant precisely.

III. MAXIMUM POWER POINT TRACKING CONTROL

Wind generation system has been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day [9-12]. Amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the MPPT controller of the WECS control system irrespective of the type of generator used [13]. The maximum power extraction algorithms researched so far can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and Hill-Climb Search control [14-17].

A. Tip speed ratio control

The TSR control method regulates the rotational speed of the generator in order to maintain the TSR to an be measured or estimated in addition to requiring the knowledge of optimum TSR of the turbine in order for the optimum value at which power extracted is maximum. This method requires both the wind speed and the turbine speed to system to be able extract maximum possible power.

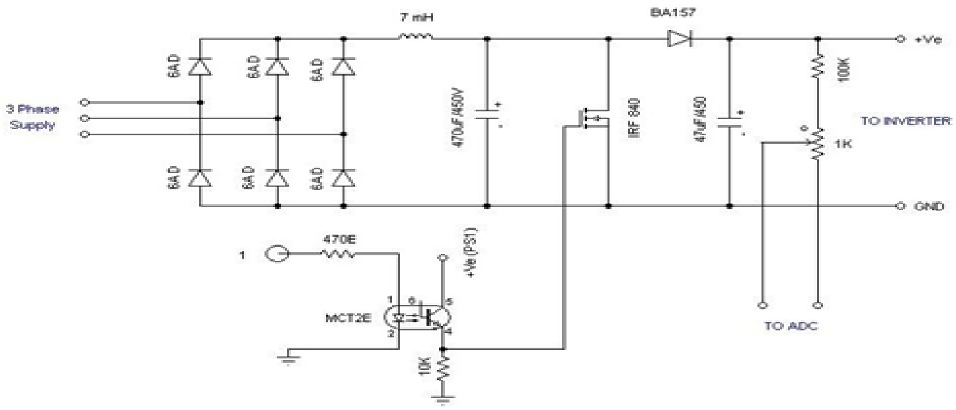

Figure 4. Tip speed ratio control of WECS

B. Hill climb search control

In Hill climb search method of MPPT control for PMSG WECS are proposed. The control algorithm proposed uses the principle of search-remember-reuse technique. The method uses memory for storing peak power points, obtained during training process, which are used later for tracking maximum power points. The principle behind this algorithm is a search-remember-reuse process. The algorithm will start from an empty intelligent memory with a relatively poor initial performance [18]. During the execution, training mode will use the searched data by advanced hill-climb search to gradually train the intelligent memory to record the training experience. The algorithm will reuse the recorded data in application mode for fast execution.

This–search-remember-reuse will repeat itself until an accurate memory of system characteristics is established. Therefore, after the algorithm is adequately trained, its power extraction performance is optimized. Since the intelligent memory is trained on-line during system operation, such a process is also referred as on-line training process [19]. The mode switch rule directs the control into one of three execution modes, namely

1. Initial mode
2. Training mode
3. Application mode.

C. Power signal feedback

In the turbine power equation is used for obtaining reference power for PSF based MPPT control of PMSG WECS[20].

$$P_{opt} = K_{opt}\omega_r^3$$

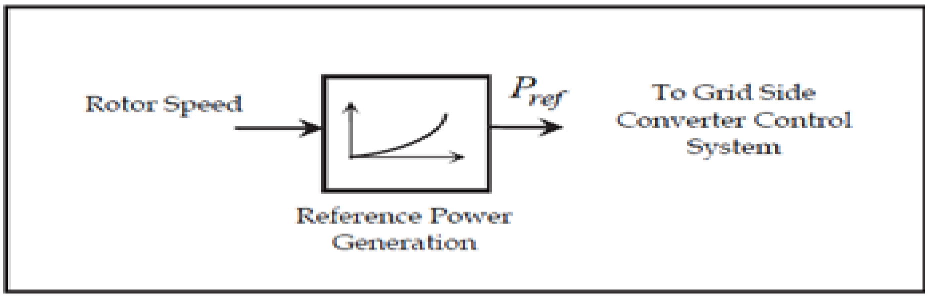

Figure 5. Reference power generation for PSF control

The PSF control block generates the reference power command P_{ref} which is then applied to the grid side converter control system for maximum power extraction.

IV. GENERALISED BLOCK DIAGRAM

The generalized block diagram of our project is given below. This is depicted in Figure 6.

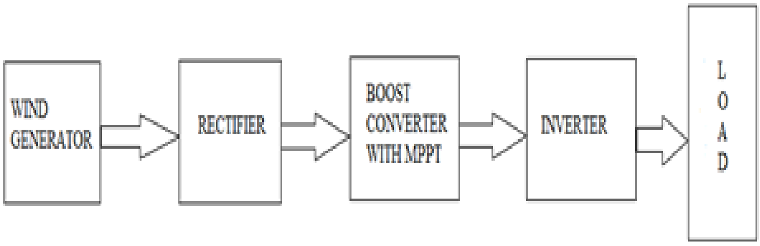

Figure 6. Block diagram of the maximum power point tracking for wind energy conversion system

The AC power generated from the wind generator is rectified to pulsating DC by 3ϕ diode rectifier. Then the rectified voltage is boosted to required level by boost converter [22]. In boost converter an MPPT algorithm is implemented to track the maximum power. The maximum power output is inverted and then given to the load.

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A. Rectifier and Boost Converter Circuit

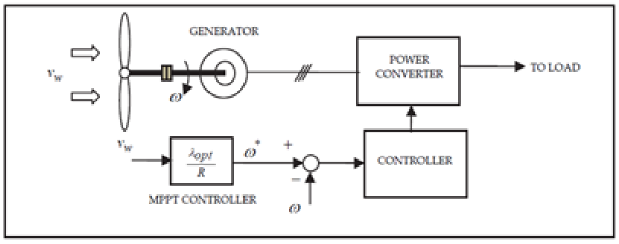

Figure 7. Rectifier and boost converter circuit

B. Dc/Dc Converter (Boost Converter)

The DC-DC to converters shows in Figure 8.The DC-to-DC converters are often used in regulated switch-mode dc power supplies and in dc motor drives applications. Frequently, the input to this converter is an unregulated dc voltage which can be obtained by rectifying an ac voltage source [21-22] .This unregulated voltage will fluctuate due to changes in the line. In order to control this unregulated dc voltage into a regulated DC output we need to use a DC-to-DC. In this model, the boost converter has been controlled to yield constant output DC voltage level, Vdc2 by varying the duty ratio, D in response to variations in Vdc1.

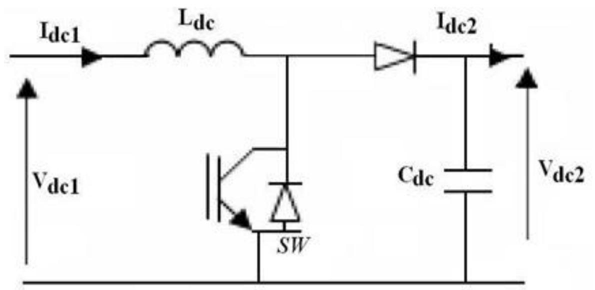

Figure 8. Boost (DC-DC) converter

V. SIMULATION MODEL AND RESULTS

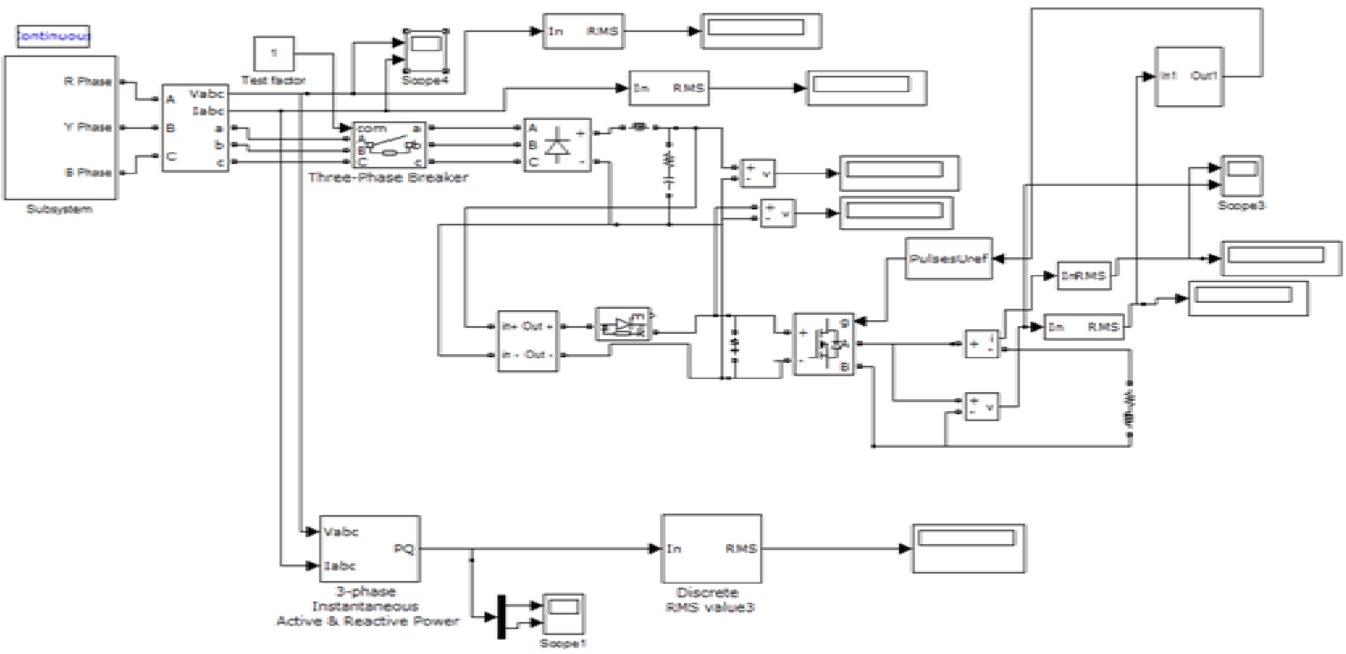

Figure 9. Simulation model of MPPT for Wind Energy Conversion System

The Simulink model of Maximum Power Point tracking for Wind Energy Conversion System. This is depicted in Figure 9.

A. Three Phase Output Waveform of Wind Generation System

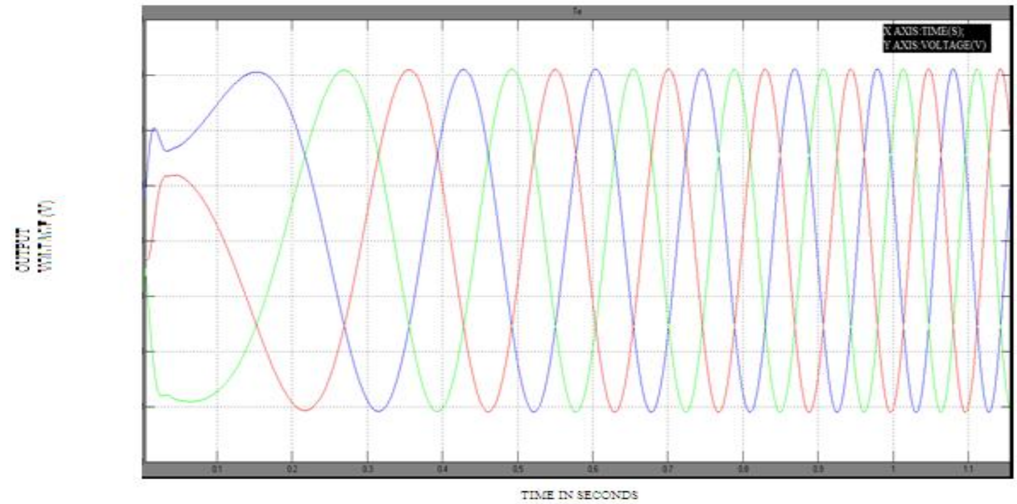

Figure 10 .Three phase output waveform

The three phase output waveform of wind generation system of output voltage Vs time. This is depicted in Figure 10

B. Output Waveform of VI Measurement Block

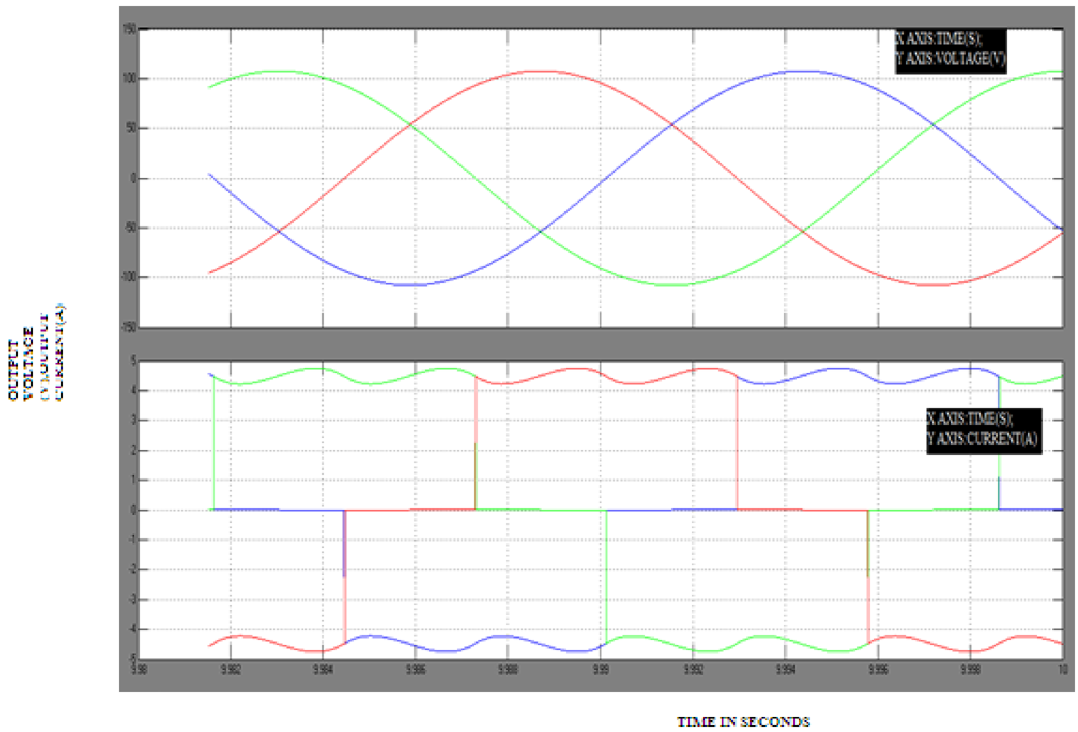

Figure 11.VI measurement waveform

The Voltage Current (VI) measurement waveform of wind generation system of output voltage and output current with respect to time. This is depicted in Figure 11.

C. Inverter Output Waveform

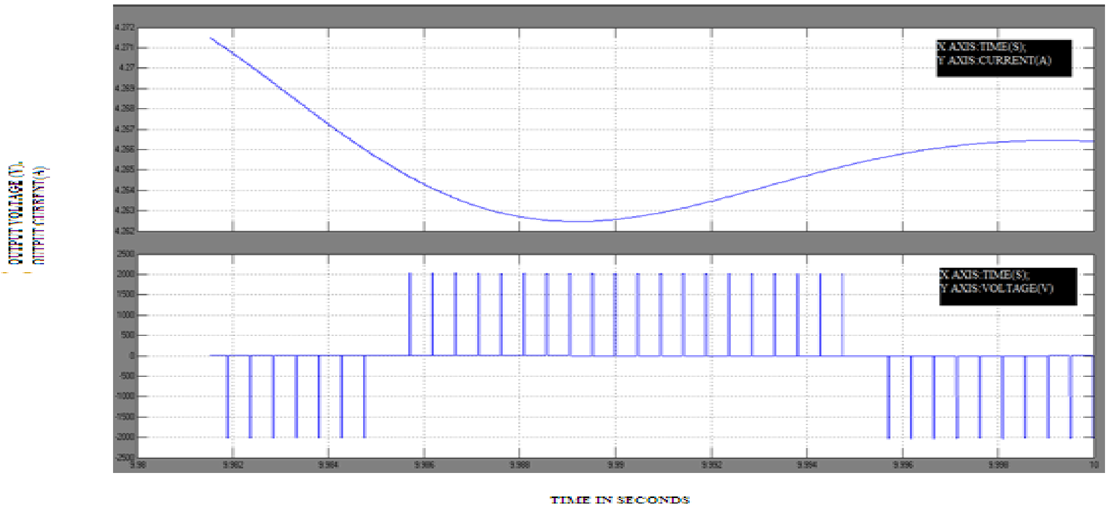

Figure 12 .Inverter voltage and current waveform

The Inverter voltage and current waveform of wind generation system of output voltage and output current with respect to time in seconds. This is depicted in Figure 12

V. CONCLUSION

In this project, the wind energy system is modeled using MATLAB Simulink. The model consists of the wind generator model, the boost converter model, and the MPPT control model. The simulation results show that the model behaves appropriately with the characteristics of the system to be modeled. Further, the modeled MPPT could track the wind energy system to find the maximum power extracted from the wind. Also the converter part is realized and MPPT is done for certain speed of wind. In future, the model will be extended to the various types of the MPPT algorithms as well as the various types of wind energy system components.

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BIOGRAPHY

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